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# KEWEENAW RESEARCH CENTER

EVALUATION OF
DIESEL ENGINED JEEP (JAPAN)

Job Order No. 318
Contract No. DA-20-113-AMC-08571(T)

January, 1967

U.S. Army Tank-Automotive Center
Warren, Michigan 48090

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MICHIGAN TECHNOLOGICAL UNIVERSITY
HOUGHTON, MICHIGAN

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# EVALUATION OF DIESEL ENGINED JEEP (JAPAN)

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U. S. Army Tank-Automotive Center

Warren, Michigan 48090

by
Keweenaw Research Center
Michigan Technological University
Houghton, Michigan 49931

## ABSTRACT

The JC3, 1/4 ton, Diesel-engined Jeep, manufactured in Japan by Mitsubishi Heavy-Industries, Limited under license from Kaiser Jeep Corporation, was evaluated for its general performance, handling, and endurance over varied terrain; including pavement, secondary roads, cross country, and snow.

The overall performance of the vehicle compared favorably with the American version of the Jeep. The Diesel engine gave it better economy, although it was more sluggish, and the engine noise was somewhat objectionable on longer duration runs. No significant maintenance problems were encountered.

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Figure 1
Japanese Jeep - Gradeability on Soft Sand

INTRODUCTION

The Shakedown Investigation of Truck, 1/4 ton, Diesel (Jeep, Japan) was conducted as Job Order No. 318 under Time and Materials Contract No. DA-20-113-AMC-08571(T) at the Keweenaw Field Station by personnel of the Keweenaw Research Center of Michigan Technological University with cooperation of personnel from the U. S. Army Tank-Automotive Center, during the fall of 1966.

The objective of the project was to evaluate the general performance characteristics of the vehicle, its handling characteristics, and endurance over varied terrain; including paved roads, secondary roads, and cross country.

Various portions of the project were conducted at the Keweenaw Field Station, but the major portion of the vehicle operation was over test routes selected in the Keweenaw County area, which is northerly from the Station. Access to the test areas was over paved roads, but within the test areas themselves the roads were either secondary or rough logging roads, and cross-country through wooded and rugged terrain.

Figure 2
Japanese Jeep - Secondary Road

## THE VEHICLE SPECIFICATIONS AND DESCRIPTION

The vehicle evaluated in this project was a Model JC3 Jeep, which was manufactured in Japan by Mitsubishi Heavy-Industries, Limited, under license from Kaiser Jeep Corporation. The general appearance and construction of the vehicle is similar to the civilian version of the Universal Jeep manufactured by the licensor in the United States. However, the engine in the test vehicle was a Model KE31-11, four cylinder, Diesel engine of the manufacturer's own make and design. This was the only significant difference between the test vehicle and its American counterpart.

The vehicle is shown in several views in Figures 1 to 4, (detailed specifications are listed in Table I). The vehicle, as tested, had a total weight of 3,750 pounds, including the driver and one passenger plus 550 pounds of payload; a rated engine horsepower of 61 at 3,600 rpm; and a maximum governed vehicle speed of 55 mph.

## DESCRIPTION OF THE TEST

The Japanese Jeep performance evaluation consisted of several phases, including the following:

A. Observation, measurement and recording of the physical characteristics of the vehicle, including photographs.

B. Performance determination including general handling characteristics; gradeability on various soils; side slope stability on sand, loose soil, and packed dirt; braking ability on wet and dry pavement and secondary roads; fuel economy under various operating conditions; and acceleration ability.

C. Mobility determination in terms of drawbar pull on varied terrain, including shallow mud, dry sand, packed clay, and paved surface. This also included mobility on a "go and no go" bases over varied cross-country terrain.

D. Durability and Reliability Determination on total of 1,000 miles of operation divided:

(1) 550 miles on cross-country running

(2) 200 miles on secondary roads

(3) 200 miles on paved roads

(4) 50 miles in mud

E. Operation, Maintenance and Deficiency Records, including hours and miles per test condition, time in preventative maintenance, time in repair, general deficiencies, and climatic conditions during the test.

## CONDUCT OF THE TEST

The evaluation of the test vehicle was conducted at the Keweenaw Field Station and in the Keweenaw County area, which is northeast from the Station, during the fall of 1966. The final running of the vehicle was conducted under snow conditions, and included several cold starts, after the vehicle had been left out over night (over 12 hours).

The mobility evaluation and cross-country running was done on old logging roads in Keweenaw County and in many instances these were roads which had not been used for vehicular traffic for many years.

Fuel economy determinations were made with a special fuel measuring system whereby fuel economy on various types of terrain, under various speeds, was readily observed. The results reported represent the average of a large number of trials on the types of terrain specified.

## RESULTS OF THE TEST

The results of the evaluation test are reported in the same

order as the corresponding descriptions of the test in preceeding section.

## Physical Characteristics

The physical characteristics of the subject vehicle are reported in Table I.

The JC3 vehicle, as reported in the manuals published by the Mitsubishi Heavy-Industries, Limited, manufacturer of the vehicle, is designated as Model JC3, which is similar to their Model J3, except that the gasoline engine has been replaced by a Diesel Engine. The reported physical characteristics which are not readily measurable are those of the manufacturer, as published in the manuals.

## Performance Determination

Several of the performance factors reported in the manufacturer's vehicle manuals were in all likelihood obtained under optimum conditions, and consequently could not be attained under the conditions specified in the Job Order test procedure.

Table II lists the actual Vehicle Performance Factors as measured under test conditions in the Keweenaw Field Station area. Gradeability ranged from 35% on soft sand up to 60% on hard sand, 55% on loose soil, and 65-70% on packed dirt.

In the side slope stability determination, the limiting condition was not imposed by the angularity of the slope, per se,

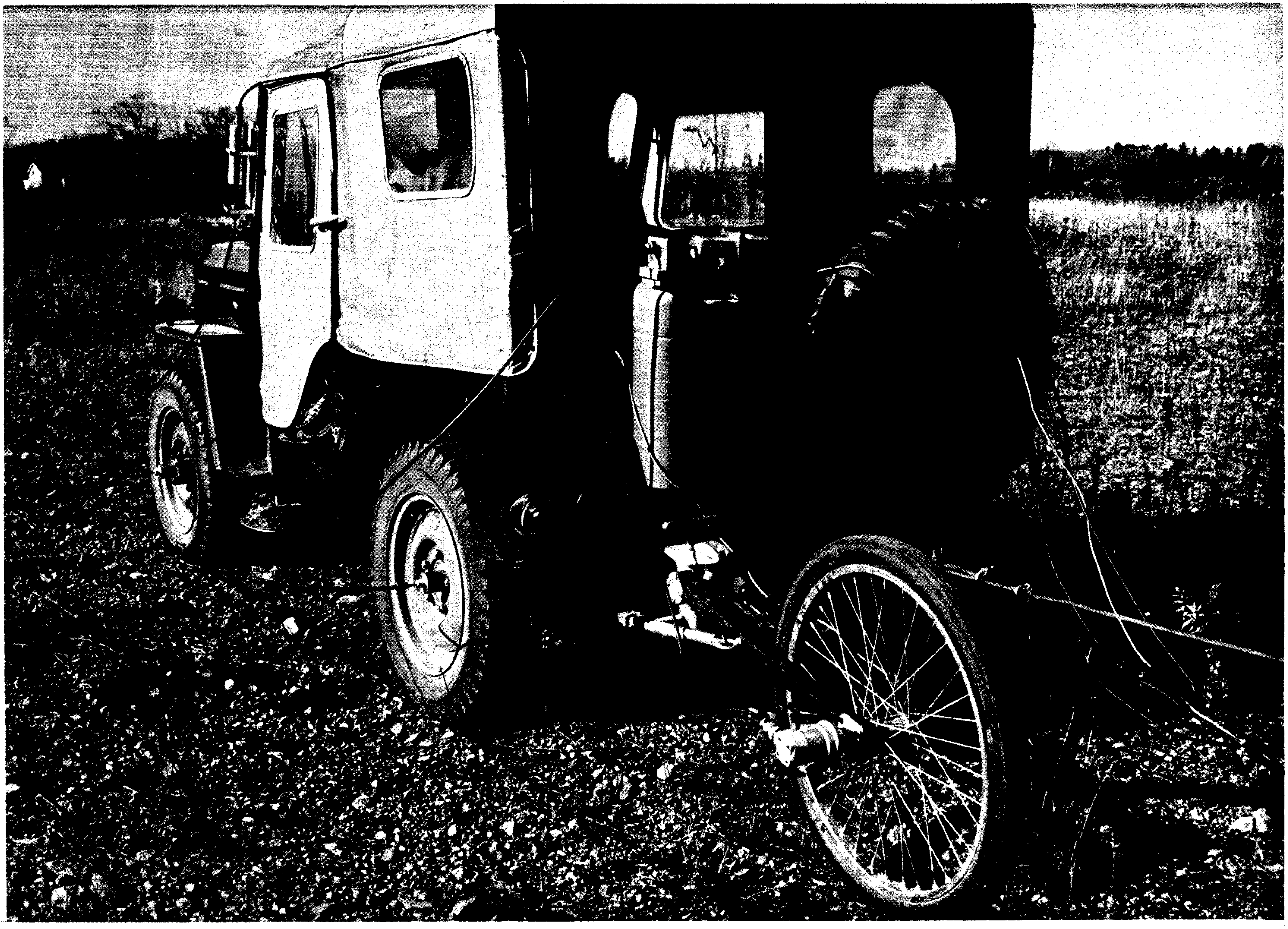

Figure 3
Drawbar Set-Up

TABLE I

Vehicle Specifications

Make: Jeep (Japan) Mitsubishi    Model: JC3    Type: Diesel, Four-Wheel Drive

Capacity: 2 persons + 550 lbs.    Serial No.: JC3000359

Vehicle Weight: 2735 lbs. (without load)    Payload: 1015 lbs.

Engine    Make: Mitsubishi    Model: KE31-11    Serial No: KE31-11828

Type: Diesel-4 cycle    Horsepower: 61 @ 3600 rpm    Torque: 97.47 lb/ft.

No. of cylinders: 4    Bore: 3.13 in.    Stroke: 4.37 in.

Compression Ratio: 18:1    Displacement: 134.2 cu. in.

Transmission Gear Ratios: 1st-2.80  2nd-1.55  3rd-1.00  Reverse-3.80

Transfer Case: high range-1.00    low range-2.46

Driving Axle Ratio: 5.38 to 1    Tires: 6:00 x 16 (front & rear)

Dimensions: Overall length: 133.4 in.    Overall width: 66.5 in.

Overall height: 74.6 in.    Wheelbase: 80 in.

Tread: 48.4 in. (front & rear) Ground Clearance 8.3 in.

Weight Distribution (without load)    Right front: 710 lbs.    Left front: 695 lbs.

Right rear: 635 lbs.    Left rear: 695 lbs.

Figure 4
Coupled to Dynamometer Vehicle - Drawbar Test

but rather by the limited shear strength of the soil conditions specified in the test procedure. On "packed dirt" the maximum side slope negotiated approached $35^{\circ}$, and even in this success was marginal. On sand the maximum slope was limited to less than $25^{\circ}$. Both of these figures are considerably less than the maximum safe tilting angle of $44^{\circ}$ specified by the manufacturer.

Braking Ability

The Japanese Jeep was tested for braking ability under various road conditions. On dry surface the average stopping distance from an initial speed of 80% of maximum, which for this vehicle was 44 mph, was 79 feet on concrete, and 101 feet on secondary gravel roads. On the same surfaces, when wet, the distances were 121 feet and 124 feet, respectively.

From initial speed of 40% of maximum, which was 22 mph, the stopping distance on dry concrete was 20 feet, and on dry gravel road 27 feet. Under wet conditions the distances were 24 feet and 28 feet, respectively.

Braking tests were also conducted on "black top" (asphaltic) pavements, but in that the tests were conducted on regularly used highways, the test strip used while dry was considered too dangerous for this type of test when wet. This type of pavement varies considerably in surface character, depending upon the surface roughness, which in turn varies with the amount of rock aggregate in the surface layer. For example, the strip used when

dry conditions prevailed was smoothly coated with asphalt, and the stopping distance from 44 mph was 86 feet, and from 22 mph, 22 feet. The first figure was somewhat greater than that for dry concrete (79 feet). On the other hand, a different test strip which has a roughened, coarse surface, the stopping distance from 44 mph, for wet conditions, was 118 feet compared to 121 feet for concrete. Normally wet black top pavement is slippery when wet, particularly if the surface is smoothly coated with fine asphaltic aggregate. Coarse, roughened pebble laden surface, on the other hand, differs very little from ordinary concrete for braking purposes, and in this case was slightly better than concrete (both wet).

Fuel Economy

Fuel consumption rates were measured while operating the vehicle over various road surfaces. On good pavement the performance varied from a low of 17.6 miles per gallon to a high of 25.4 miles per gallon, with an overall average of 20.1 miles per gallon at 45 mph.

On secondary roads the average fuel economy was 19.8 miles per gallon at 21 mph. On cross-country running the average was 16.2 mpg at 11.2 mph. Under heavy snow conditions, which required low range, four-wheel drive operation, the figures dropped to 11.0 mpg at 10.4 mph.

TABLE II

Vehicle Performance Factors

Steering: 14:1 ratio. No detectable over or under steer.

Handling: Satisfactory

Ride: Fair

Stability: Erratic on severe braking; otherwise satisfactory.

| | | | |
|---|---|---|---|
| Maximum Gradeability; Percent: | Sand (Hard) 60% (Soft) 35% | Loose Soil 55% | Packed Dirt 65-70% |

Side Slope Stability: $30\text{-}35^{\circ}$ on packed dirt $20\text{-}25^{\circ}$ on sand

| | | 80% max. speed (44 mph) | 40% max. speed (22 mph) |
|---|---|---|---|
| Braking Ability: (Stopping distance in feet) | Dry Pavement (concrete) | 79 | 20 |
| | Wet Pavement (concrete) | 121 | 24 |
| | Dry Secondary Road | 101 | 27 |
| | Wet Secondary Road | 124 | 28 |

Fuel Economy: Cruise on Paved Highway-20.1 miles/gal @ 45 mph

Secondary Roads-19.8 miles/gal @ 21 mph

Cross Country Courses-16.2 miles/gal @ 11.2 mph

Cross Country, heavy snow-11.0 miles/gal @ 10.4 mph

Acceleration: 0 to 55 mph in 40 seconds - without load

0 to 55 mph in 45 seconds - with load

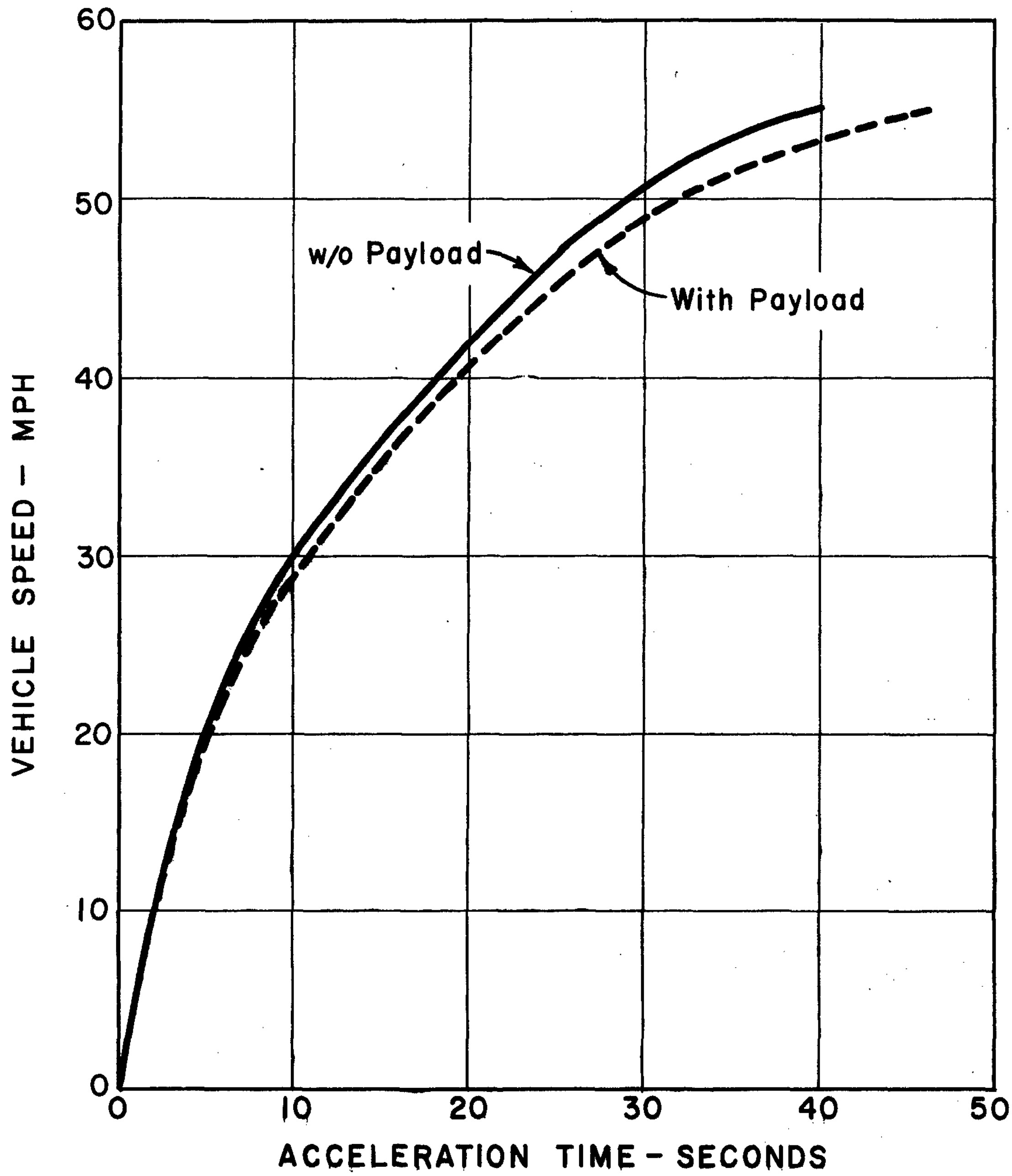


Figure 5
Japanese Jeep - Acceleration Rate

## Acceleration Rate

Acceleration tests conducted on smooth, level concrete pavement, showed that 40 seconds were required to reach a governed maximum speed of 55 mph, without payload, and 45 seconds for this same speed with payload. In that the engine was equipped with a speed governor the time for the last portion of the acceleration period varied considerably during the test. Possibly a more reliable comparison would be the 29 seconds to reach 50 mph, unloaded, and 32 seconds when loaded. A graph of this is shown in Figure 5.

## Mobility Determination

The first portion of the mobility test involved a drawbar pull measurement on various soils. The graphical presentation of the results of this test are shown in Figure 6 .

The maximum drawbar pull attained was 2,450 pounds on dry pavement with approximately six percent slip, the maximum attainable. This corresponds to a drawbar pull/weight ratio of 0.65. The limiting factor on the maximum slip in this case was engine power.

On firm sod the maximum drawbar pull was 2,100 pounds, at a slip of 23 percent, with a maximum attainable slip of 46 percent. Sand conditions limited drawbar pull to a maximum of 1,950 pounds at 35 percent slip, and mud further reduced the drawbar pull to 775 pounds with 40 percent slip.

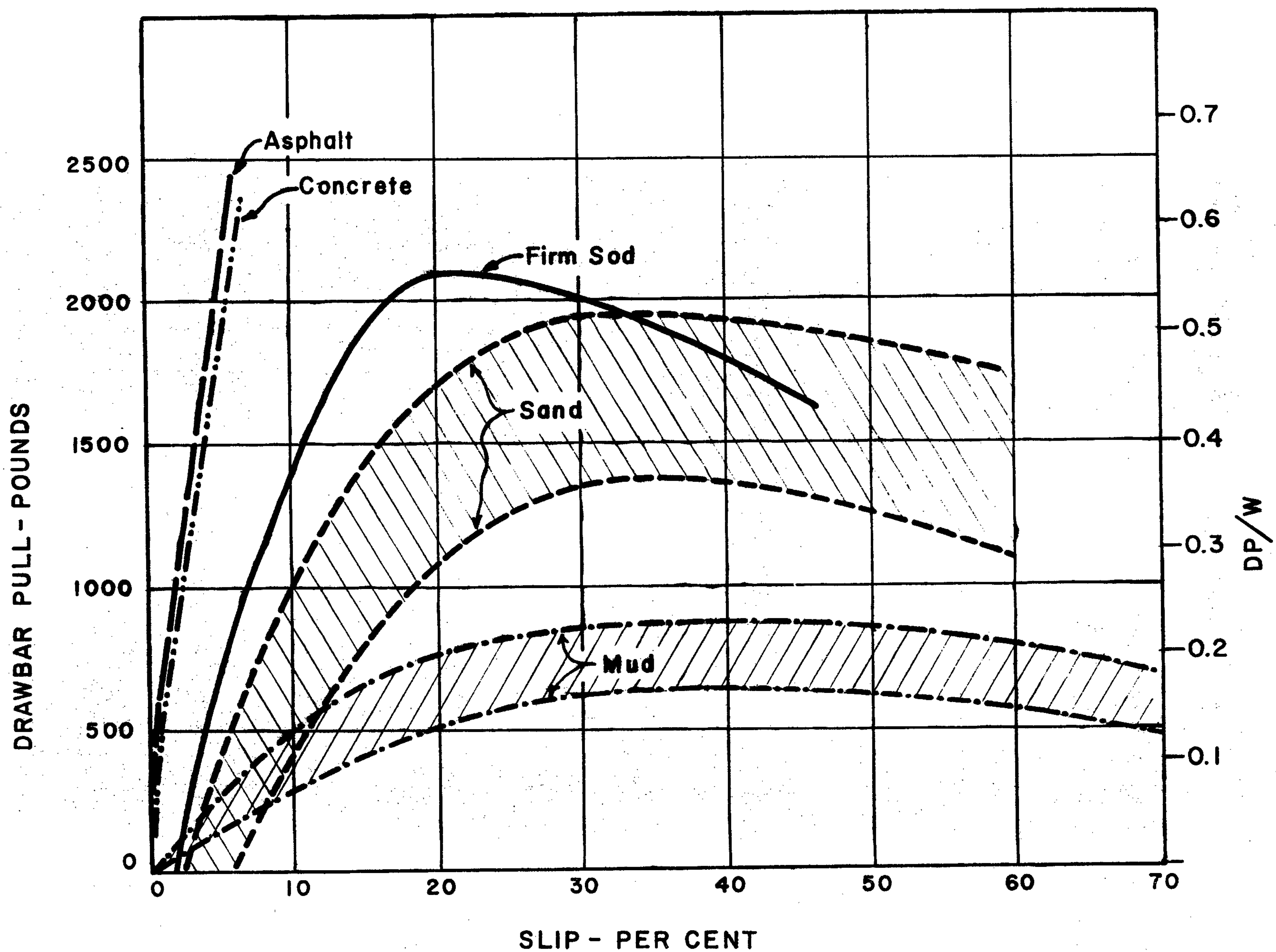


Figure 6
Drawbar Pull vs. Slip

Mobility Limits on "Go and No Go" Basis

In addition to the drawbar pull test, further mobility measurements involved qualitative observations on various cross-country courses. The vehicle was driven over a wide variety of cross country test routes, and in some cases over marginally negotiable terrain.

Vehicle mobility limits usually involved getting "hung-up" on the under carriage. This occured in soft soil and also in snow which was encountered at the end of the vehicle test. In several instances the vehicle became hung-up on protruding obstacles; and in other cases, on ordinary soft soil surfaces, after the wheels dug themselves into soft ruts. A similar problem was encountered when snow accumulation caused decreased traction and high resistance to motion, and finally hanging-up on the underbelly. Mobility limiting snow conditions finally required sending in a track-laying tractor into the test area to retrieve the vehicle when it became immobilized in snow.

To present a description of the results of this portion of the test on a quantitative basis would be nearly impossible. The vehicle mobility was judged by an experienced test driver to have performance comparable to the military M38 Jeep. This is understandable since the basic undercarriage, the part which usually caused the immobilization, was similar on the Japanese

Jeep to the Military M38 Jeep. On no occasion was power limitation a cause of immobilization. A series of photographs, Figures 1A to 12A, inclusive, shows the vehicle on various test courses, both on summer and winter terrain.

## Durability and Reliability

No major problems were encountered with the vehicle durability or reliability during the actual conduct of the test. However, the original Diesel engine in the vehicle was replaced at 973 kilometers, (604 miles), prior to the test because of damage to the engine. This was caused by the camshaft shifting endwise in its bearings, which interfered with proper cam operation and ultimately caused an engine failure.

The same problem with the camshaft was encountered in both vehicles of the same make, now at the Keweenaw Field Station, while the vehicles were in transit between Detroit and Houghton. One vehicle had an engine failure enroute, the other arrived under its own power but already slightly damaged. The vehicle which failed enroute was used in this project, but with a new engine, as indicated above.

Basically, the difficulty was that the cap screw which holds the drive gear on the camshaft worked loose and allowed the camshaft to shift rearward in its bearings. As a consequence the cam lobes no longer were in proper alignment with the valve lifters and caused the latter to break.

In one engine, the broken lifter lodged between the connecting rod and cylinder block, damaging both members. This engine was the one replaced. In the second engine the malfunction was discovered before any major damage occured to the engine.

The remedy for the problem was relatively simple. It was found that the cap screw used was too short, thus engaging only a few threads, and this was replaced with a longer cap screw. As a further safety precaution the cap screw was lock wired. No further difficulty was encountered in this matter, nor were there any other major problems with either the engine or the running gear of the vehicle.

One minor problem was encountered with the engine starter. The engaging mechanism malfunctioned and the starter was replaced, with no further trouble from this source.

The total mileage accumulated on the test vehicle at the end of the test was 6219 miles, which includes the miles accumulated during the formal test, and while the vehicle had been in use as a general service vehicle at the Keweenaw Field Station, and prior to its arrival at KFS.

## Cold Starts

Although the test procedure did not specify cold starting observations, in that the evaluation extended into the cold weather season data has been recorded for this. During this period the

temperatures ranged downward to -16°F, the coldest recorded for any cold start attempts.

The first failure to start was encountered at a -6°F temperature. Three tries were made using the normal engine starting aids (glow plugs), but the engine would not fire. At that time the vehicle still had SAE 20 oil in the crankcase, the oil used during the moderate fall weather.

The crankcase oil was changed to SAE 10, and since that time cold starts have been made successfully at temperatures down to -7°F. At this temperature five attempts were required before the vehicle started. Each attempt consists of first heating the glow plugs, accomplished by turning the normal starter switch counterclockwise. An indicator on the instrument panel, consisting of a resistance wire in the same circuit as the glow plugs, glows red when the glow plugs are heated. During starter engagement, accomplished by turning the same switch clockwise, the glow plugs are no longer energized and must rely on residual heat. On the fifth attempt, at this -7°F temperature, the engine fired in 19 seconds and ran smooth in 25 seconds.

At the lowest temperature encountered, -16°F, the engine could not be started. A summary of the cold starts is shown in Table III.

TABLE III

Cold Starts

| Ambient Temperature (°F) | Time-First Attempt (Seconds) To Fire | Time-First Attempt (Seconds) Sustaining | Time-Second Attempt (Seconds) To Fire | Time-Second Attempt (Seconds) Sustaining |
|---|---|---|---|---|
| SAE#20 Oil in Crankcase | | | | |
| 25 | 4 | 5 | | |
| 22 | 10 | 11 | | |
| 17 | 19 | 22 | | |
| 15 | 24 | 30 | | |
| 12 | 28 | 35 | | |
| -6 | No start - three attempts | | | |
| SAE#10 Oil in Crankcase | | | | |
| 22 | 5 | 9 | | |
| 8 | 15 | 20 | | |
| 4 | 20 | No Fire | 10 | 15 |
| -2 | 20 | No Fire | 20 | 25 |
| -7 | Successful start after five attempts. On final attempt fired in 19 seconds, running smooth in 25 seconds. | | | |
| -16 | Engine could not be started. | | | |

A P P E N D I X

Figure 1A
Drawbar Test in Sand

Figure 2A
Side Stability Test on Soft Sand

Figure 3A
Side Slope Stability Test on Packed Dirt


Figure 4A
Hung-Up on Rough Cross Country Course

Figure 5A
Rough Cross Country Trail

Figure 6A
Creek Crossing on Cross Country Course

Figure 7A
Rough Cross Country Course with Snow

Figure 8A
Gradeability Test on Grassy Slope

Figure 9A
Gradeability Test on Packed Dirt

Figure 10A
Gradeability Test on Packed Dirt


Figure 11A
Mobility Test in Snow

Figure 12A
Mobility Test on Muddy Roads

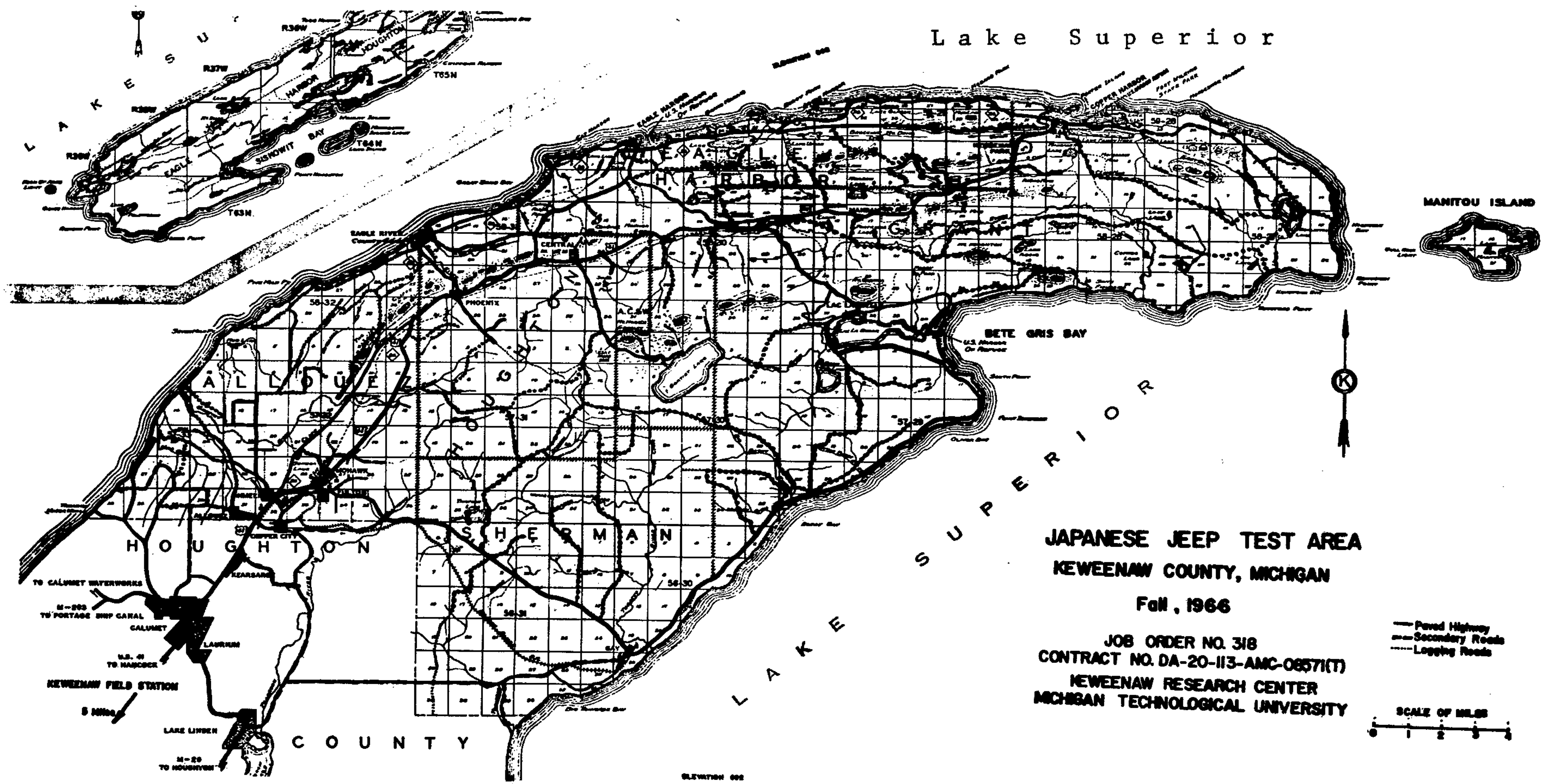


Figure 13
Keweenaw County Map - Roads Traversed Indicated

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13. ABSTRACT


The JC3, ¼ ton, Diesel-engined Jeep, manufactured in Japan by Mitsubishi Heavy-Incustries, Limited under license from Kaiser Jeep Corporation, was evaluated for its general performance, handling, and endurance over varied terain; including pavement, secondary roads, cross country, and snow.

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